

DISCHARGE MEASUREMENT

EG&G ROCKY FLATS PLANT	Manual:	5-21000-OPS
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U S Environmental Protection Agency Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual Environmental Services Division, Region IV Athens, GA April 1986

U S Department of the Interior Hydraulic Measurement and Computation "Discharge Measurements at Gaging Stations " Book 1, Chapter 11, Geological Survey Reston, VA 1965

U S Department of the Interior National Handbook of Recommended Methods for Water-Data Acquisition Office of Water Data Coordination, Geological Survey Reston, VA, 1977

4.2 INTERNAL REFERENCES

A related SOP cross-referenced by this SOP is

- SOP SW 1, Surface Water Data Collection Activities

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5.0 METHODS

This SOP describes Environmental Protection Agency (EPA)-approved discharge measurement methods. Methods are based on known conditions at RFP. A variety of discharge measurement methods are required because flow conditions differ from site to site. In consideration of these varied conditions, this SOP describes possible flow conditions that may be encountered and describes methods that are to be used based on the site-specific flow conditions.

Because of the dynamic nature of surface water characteristics, flow measurement by the methods described in this document may be impossible at some sites. If immeasurable flow conditions are encountered at a surface water data collection site, the field crew will attempt to measure flow at a point upstream or downstream of the site. Whether or not a measurement is made, the crew will note the conditions that inhibited accurate flow measurement at the designated site.

Selection of discharge measurement methods is based on the following existing conditions at RFP:

- Flumes to be installed at RFP are Parshall flumes
- Pipes in and around the protected area (PA) contain gravity flow. (These may be difficult to reach with a velocity measuring device)
- Many stream channels are rocky and historical stream discharge measurements indicate that portable flumes failed to adequately contain flow.

In view of these existing physical constraints, Table SW 4-1, Discharge Measurement Methods Based on the Type of Site, will be consulted to select the method used at a particular site.

The control structure (flume) method should be used for discharge measurements in streams or ditches when flumes are in place and operational. The volumetric method, is to be used only for measurement of discharge from pipes.

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Table SW.4-1

DISCHARGE MEASUREMENT METHODS BASED ON THE TYPE OF SITE

<u>Type of Site</u>	<u>Method</u>
Pipe	Volumetric
Flume	Flume
Flume, with aquatic vegetation	Velocity-area
Stream channel, no flume	Velocity-area
Ditch	Velocity-area
NPDES discharge locations	Flume with totalizer readings

It is recommended that the velocity-area method be used at specific sites where aquatic vegetation or other materials located in the flume or in the channel downstream from the flume may produce backwater conditions. Backwater conditions are discussed in Subsection 5.1.3.2, which describes required measurement conditions for flumes

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5.1 BUCKET AND STOPWATCH VOLUMETRIC METHOD

The volumetric method is a simple and accurate method for measuring flow from small discharges and will be utilized at RFP to measure gravity flow discharges from pipe outlets. This method involves observing the time required to fill a container of known capacity, or the time required to partly fill a calibrated container to a known volume. Alternatively, in the case of measuring discharge remotely in a sump or standpipe setting, the volumetric method may be performed by capturing flow in a container for a set period of time no less than 10 seconds. This volume of water is then measured and discharge is determined.

5.1.1 Equipment

The "bucket and stopwatch" technique is particularly useful for the measurement of small flows. Equipment required to make this measurement is a calibrated container and a stopwatch. For measurements at RFP, calibrated containers of varying sizes will include:

- 5-gallon calibrated bucket
- 2-liter graduated cylinder
- 1-liter graduated cylinder
- 1-liter beaker
- 500-milliliter beaker
- 250-milliliter beaker

Extension rods will be used to hold a container for capturing flow in enclosed areas containing discharging pipes.

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5.1.2 Maintenance and Calibration Procedures

Graduated cylinders are incremented in terms of milliliters and can be easily converted to gallons. The incremental volume of a 5-gallon bucket can be determined by adding known volumes of water and recording the depth after each addition.

5.1.3 Field Procedures

In accordance with SOP SW 1, Surface Water Data Collection Activities, the field crew will assess the type of site being visited. Upon arrival at the site, the technicians will evaluate the flow conditions to select the appropriate method for flow measurement. If the flow conditions meet those outlined in Subsection 5.1.1, then the technicians will observe and use judgement in approximating the flow volume and will select an appropriately sized volumetric container to use the volumetric method of flow measurement.

A technician will use a stopwatch to measure the time required to fill a volumetric container. The technician will time flow into the container for a minimum of 10 seconds. Three consecutive measurements will be made and noted, and the results averaged to determine the discharge.

If remote measurement is necessary, a container will be attached to an extension rod. The technician will time flow for a minimum of 10 seconds. The volume of water will then be poured into a calibrated container, measured, and recorded. Three such measurements will be made, noted, and the results averaged to determine the discharge.

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5.1.4 Discharge Calculations

Discharge will be determined initially in gallons per second (gal/s) or in milliliters per second (ml/s). These values will be noted, but the averaged value will be reported in cubic feet per second (cfs). Calculations will be performed as follows:

- Record each of the three measurements in terms of gallons per second or milliliters per second, depending on the volumetric container.
- If one of the three measurements is 50 percent or more different from the other two measurements, then this value will not be used. Instead, three additional measurements will be taken and, provided that none of these measurements differs by greater than 50 percent from the other two measurements, these values will be used.
- Average the three values.
- Convert the averaged value to cfs as follows:
 - to convert ml/s to cfs, multiply by 3.53×10^{-5}
 - to convert gal/s to cfs, multiply by 0.134
- Record discharge in cubic feet per second (cfs).

5.2 VELOCITY-AREA METHOD

The vertical axis current meter has been selected to perform velocity-area method discharge measurements. A common type of vertical axis current meter is the Price meter, type AA (see

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Figure SW 4-1) A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined. The number of revolutions of the rotor is obtained by an electrical circuit through the contact chamber. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. The electrical impulse produces an audible click in a headphone. The intervals during which meter revolutions are counted are timed with a stopwatch.

A Price pygmy meter will be used in shallow depths and low velocities (see Figure SW 4-1). The pygmy meter is scaled two-fifths as large as the type AA meter. The pygmy meter makes one contact (click) per revolution while the type AA meter can make one click per revolution or one click per five revolutions. The predominant flow conditions in channelized streams at RFP indicate that the pygmy meter will be used far more frequently than the Price AA meter.

5.2.1 Introduction

The current meter measures velocity at a point. The velocity-area method requires measurement of the mean velocity in selected subsections of the stream cross section. By dividing the stream width into subsections, discharge becomes the total of discharges measured in each subsection (see Figure SW 4-2). Velocity (v) is measured at each subsection, and discharge becomes the sum of the products of each point velocity and cross sectional area of each subsection.

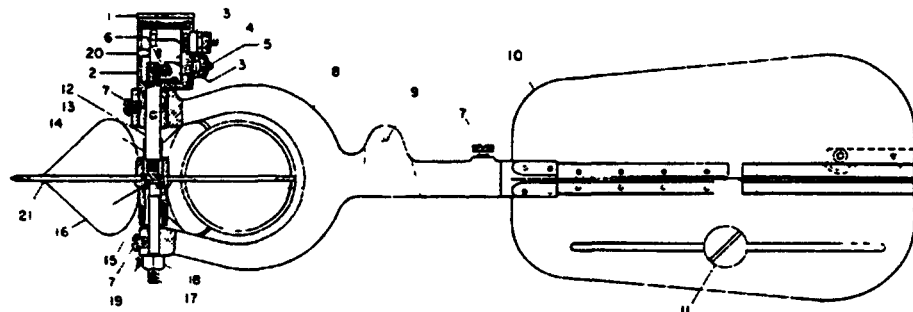
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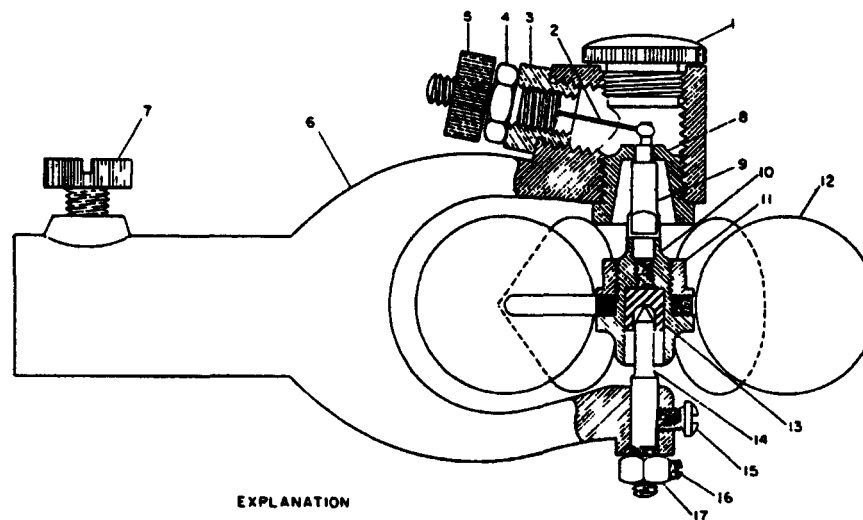
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EXPLANATION

- | | |
|---|---|
| 1 Cap for contact chamber | 11 Balance weight |
| 2 Contact chamber | 12 Shaft |
| 3 Insulating bushing for contact binding post | 13 Bucket-wheel hub |
| 4 Single-contact binding post | 14 Bucket-wheel hub nut |
| 5 Penie-contact binding post | 15 Raising nut |
| 6 Penie gear | 16 Pivot bearing |
| 7 Set screw | 17 Pivot |
| 8 Yoke | 18 Pivot-adjusting nut |
| 9 Hole for hanger screw | 19 Keeper screw for pivot-adjusting nut |
| 10 Tailpiece | 20 Bearing lug |
| | 21 Bucket wheel |

Assembly diagram of type-AA Price current meter



EXPLANATION

- | | |
|-----------------------------------|-------------------------|
| 1 Cap for contact chamber | 10 Bucket-wheel hub |
| 2 Binding-post beaded wire | 11 Bucket-wheel hub nut |
| 3 Binding post insulating bushing | 12 Bucket wheel |
| 4 Binding-post body | 13 Pivot bearing |
| 5 Binding-post nut | 14 Pivot |
| 6 Yoke | 15 Pivot set screw |
| 7 Yoke set screw | 16 Pivot-adjusting nut |
| 8 Upper bearing | 17 Pivot-adjusting nut |
| 9 Shaft | |

Assembly diagram of pygmy current meter

**SOURCE WRI BOOK 8,
CHAPTER B2**

(4011-940-0140-940)

Job No 4011

Prepared by MAS

Date 03/01/92

**PRICE TYPE AA METER, TOP;
PRICE PYGMY METER, BOTTOM**

FIGURE SW.4-1

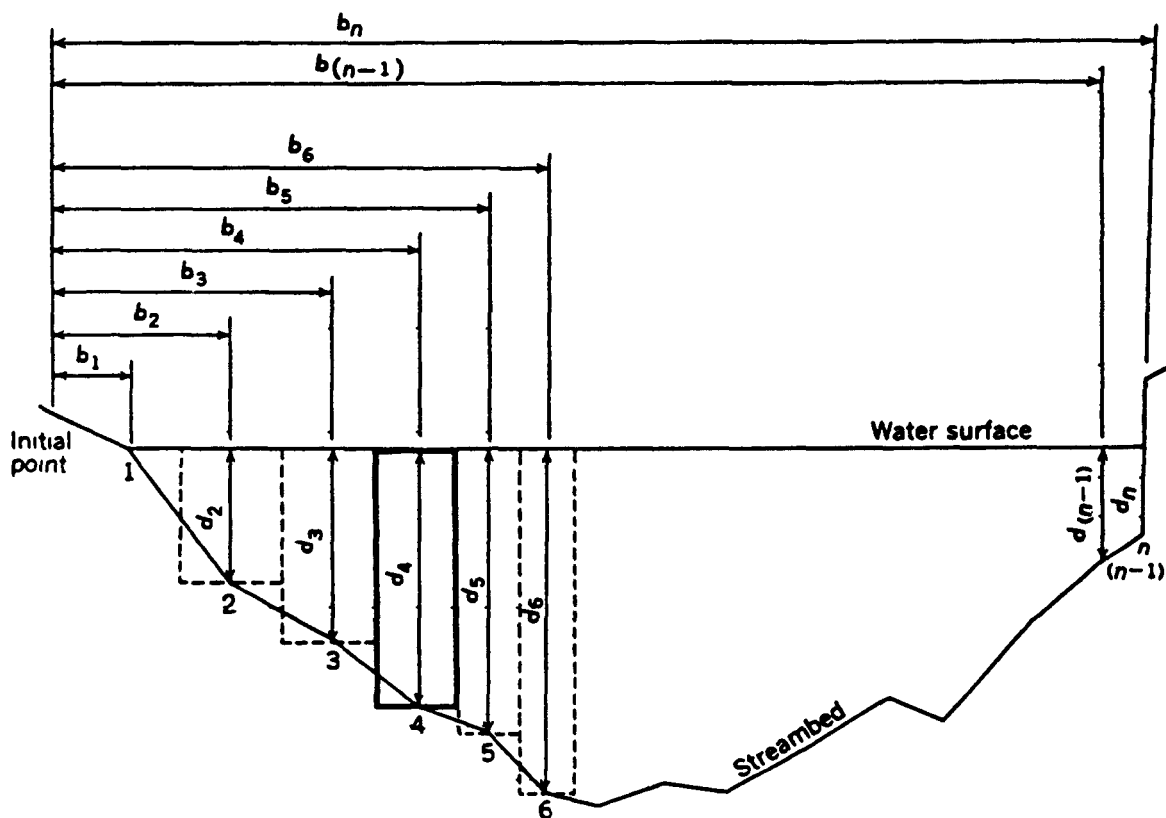
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EXPLANATION

1, 2, 3	n	Observation verticals
$b_1, b_2, b_3,$	b_n	Distance, in feet or meters, from the initial point to the observation vertical
$d_1, d_2, d_3,$	d_n	Depth of water, in feet or meters, at the observation vertical
Dashed lines		Boundaries of subsections, one heavily outlined is discussed in text

SOURCE:
GEOLOGICAL SURVEY
WATER-SUPPLY
PAPER 2175, 1982

(4011-940-0141-940)

Job No 4011

Prepared by MAS

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DEFINITION SKETCH OF MIDSECTION
METHOD OF COMPUTING CROSS-SECTION
AREA FOR DISCHARGE MEASUREMENTS

FIGURE SW 4-2

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$$Q = \Sigma va$$

Where Q is total discharge, v is point velocity, and a is the area of the subsection

In general, the hydrographer measuring discharge should strive to measure no more than 5% of the flow in any one subsection. However, for small streams this is often impossible. Therefore, the hydrographer should divide the channel cross-section into as many subsections as possible and make 2 complete discharge measurements using different sections for each. Further, subsections need not be of identical width. Velocities near banks are generally lower than velocities near the center of streams, thus these subsections may be wider than subsections near the center. Subsections will also be more closely spaced if a stream has an unusually deep portion in the cross section, or if velocities are higher than usual for the cross section. The minimum section width for the AA-meter is 40 feet and the minimum section width for the pygmy meter is 30 feet.

Typically, velocities will be measured by current meter for a 40-70 second period. It is recognized that 40 to 70 seconds is not long enough to ensure the accuracy of a single point-observation of velocity. However, because pulsations caused by turbulent and eddying effects are random and because velocity observations during a discharge measurement are made at several verticals, there is little likelihood that the pulsations will bias the total measured discharge of a stream. Longer periods of current meter observation at a point are not used because (1) it is desirable to complete a discharge measurement before the stage changes significantly and, (2) the use of longer observation periods may add significantly to the operating cost of data collection.

5.2.2 Required Measurement Conditions

In order to make a velocity-area discharge measurement, the following conditions are required.

- 1 The stream must be channelized, that is, banks must channel the stream flow

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2. Depth must be greater than 0.2 foot across most of the cross section being measured.

The ideal channel cross section is trapezoidal in shape, completely smooth in boundary materials, and possesses a uniform velocity distribution. It is recognized that no such cross sectional areas exist at RFP. Therefore, minor modifications to the stream channels will be used in order to optimize measurement conditions. These modifications may include removal of aquatic vegetation, ice, and moving small stones which impact velocity upstream or downstream of the cross section.

Current meter measurements will be made by wading, if conditions permit. The type AA or pygmy meter is used for wading measurements. Table SW 4-2 lists the type of meter and velocity method to be used for wading measurements at various depths. The hydrographer should stand at arm's length to the side of the meter.

TABLE SW.4-2
VELOCITY MEASURING POINT SELECTION

Stream Depth (ft)	Type of Meter	Velocity Measuring Point(s) (% of Depth)
2.5 or more	Type AA	0.2 and 0.8
1.5 - 2.5	Optional	0.6
0.3 - 1.5	Optional	0.6
<0.3	Pygmy	0.5

Some departure from Table SW 4-2 will be permitted. If the stream velocity is high it may not be possible to count clicks with a pygmy meter. If this occurs the type AA meter should be used. Do not switch from one meter to another in the middle of a discharge measurement.

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Under open channel laminar flow conditions, the effect of fluid contact with the bed of a stream channel and the air is a vertical distribution of velocities. Consistent with this velocity distribution, actual observation and mathematical theory has demonstrated that a single measurement of velocity taken at 0.6-depth or the average of two point velocities taken at 0.2 and 0.8 of the depth below the surface accurately results in mean velocity in the vertical (U S G S Water-Supply Paper 2175,133-134pp)

If the stream is generally less than 2.5 feet deep, use the six-tenths (0.6) method. If the stream is generally greater than 2.5 feet, the two-and-eight-tenths (0.2 and 0.8) method, also known as the two-point method, will be used. A complete discussion concerning how to set the wading rod to place the current meter at proper depths is contained in Subsection 5.1.2.5.

In the 0.6-depth method, an observation of velocity made in the vertical at 0.6 of the depth below the surface is used as the mean velocity in the vertical. In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of the two observations is taken as the mean velocity in the vertical.

A depth of 1.25 feet will accommodate the 0.6-depth method without causing the meter to be set closer than 0.5 feet from the streambed, if the meter is set any closer to the streambed, it will under-register the velocity. If the technician is at a measurement section that has only a few verticals shallower than 1.25 feet, the technician should use the type AA meter rather than the pygmy meter if the depth is no less than 0.5 feet at any vertical.

Vertical axis current meters do not register velocities accurately when placed close to a vertical wall. A Price meter held close to a right-bank vertical wall will under-register because the slower water velocity near the wall strikes the effective (concave) face of the cups. The converse is true at a left-bank vertical wall. (The terms "left bank" and "right bank" designate direction from the center of

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a stream for an observer facing downstream) The Price meter also under-registers when positioned close to the water surface or close to the streambed

5.2.3 Equipment

Current meters, timers, depth and width measuring devices, and a means of counting meter revolutions are needed for measurement of discharge The equipment includes

- Top-setting wading rod and Current meter
- Width-measuring devices, either engineer's tape or tagline
- Digital counter or headset and stopwatch
- Current meter rating tables
- Stakes for width-measuring devices
- Calculator

5.2.3.1 Top-setting Wading Rod The depth-measuring device that will be used is the wading rod The current meter is attached to the wading rod The top-setting rod is preferred for use at RFP because of the convenience in setting the meter at the proper depth and because the hydrographer's hands remain dry in the process The top-setting wading rod has a 1/2-inch hexagonal main rod for measuring depth and a 3/8-inch diameter round rod for setting the position of the current meter

5.2.3.2 Current Meter. See description in Subsection 5.1.2.

5.2.3.3 Engineer's Tape or Tagline. Tape measures or premarked taglines are used for stream width measurements Orientation normal to the flow pattern of the stream and elimination of most of the sag, through support or tension, are recommended for improved accuracy.

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5.2.3.4 Digital Revolution Counter or Headset The digital revolution counter attaches to an electronic connection at the top of the wading rod. The digital display shows the number of seconds of elapsed time. The hydrographer stops the counter after 40 or more seconds, and the counter automatically displays the velocity.

If the digital counters are unavailable, the headset will be used as a means for determining the number of revolutions. A headset attaches to an electronic connection at the upper end of the wading rod. The hydrographer wears this headset to listen to the audible clicking sounds produced by current meter revolutions. The number of rotations are counted and timed. Velocities as a function of time are listed on a current meter rating chart, which is kept in the current-meter carrying case.

5.2.3.5 Stopwatch. A stopwatch is used to measure time during which velocity is measured at each point in the cross section.

5.2.4 Maintenance and Calibration Procedures

Prior to and following the use of the current meter, spin tests will be conducted to ensure that the unit performs acceptably. The spin test will be performed in an enclosed area, such as in the cab or in the enclosed rear of a truck, to prevent wind interference. The test is to be performed prior to attaching the current meter to the wading rod. While holding the meter steady in an area sheltered from breezes, the technicians will spin the rotor and then press the start button on the stopwatch. The technician will observe the meter until the rotor ceases to spin.

The duration of the spin for the pygmy meter will be more than 40 seconds, and for the Price AA meter, it will be more than 90 seconds. If the meter fails to meet the time-of-spin criteria, the meter will be cleaned and oiled before use. If the meter continues to spin well beyond these time

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limits, the record will indicate that the meter spun for 40+ seconds, in the case of the pygmy meter, or for 90+ seconds in the case of the Price AA meter

To ensure reliable observations of velocity, it is necessary that the current meter be kept in good condition. Before and after each discharge measurement, the meter cups or vanes, pivot and bearing, and shaft will be examined for damage, wear, or faulty alignment. During measurements, the meter will be observed periodically when it is out of the water to be sure that the rotor spins freely.

Meters will be cleaned and oiled daily when in use. If measurements are made in sediment-laden water, the meter will be cleaned immediately after each measurement. After oiling, wipe away any excess oil and spin the rotor to make sure that it operates freely. If the rotor stops abruptly, the cause of the trouble will be sought and corrected before using the meter.

In addition to meter maintenance, the entire unit consisting of current meter, wading rod, and digital counter or headset will be checked before departure to the field each day as follows.

- Attach the current meter and digital counter/headset to the wading rod.
- Check the digital counter by ensuring that the readout is visible when the unit is turned on.
- If a headset is being used
 - Spin the current meter to ensure that audible clicks occur

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- If audible clicks do not occur, the following steps should be taken
- Check that electronic connections are tight
- Check that the cat's whisker lightly contacts the upper part of the shaft
- Spin again If audible clicks still do not occur, check that the battery in the headset is properly aligned. Replace the battery, if necessary

5.2.5 Field Procedures

5.2.5.1 Overview. In accordance with SW 1, Surface Water Data Collection Activities, the field crew will determine the type of site being visited. Upon arrival at the site, the field technicians will evaluate the flow conditions to determine which measurement method is appropriate. Based on flow conditions, either the Price AA meter or the pygmy meter will be selected to perform a velocity-area measurement.

At each measurement point (or section) across the stream cross section, depth is measured prior to measurement of velocity. Place the wading rod about 0.5 feet downstream from the tagline to prevent contact with the current meter when the meter is lowered into measuring position. Place the wading rod in the stream so the base plate rests on the streambed. The depth of water is read from the graduated main rod. The main rod is graduated into 0.1-foot increments. These increments are indicated by a single score in the metal. Half-foot increments are marked by two scores in the metal, and each foot is marked by three scores in the metal. A vernier scale on the upper handle of the rod corresponds to 0.1-foot increments, and has 1 through 9 in raised numbers.

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next to raised marks. A sliding, adjustable rod, known as the setting rod, to which the meter is attached, has single scored marks which are aligned with values on the vernier scale.

In high velocity areas, it is recommended that depth be read as the value between depth on the upstream side of the rod and depth on the downstream side of the rod. Depth is measured to the nearest 0.02 foot. This depth is used to set the vertical location of the current meter.

The setting rod is then adjusted downward so that the scored mark of the setting rod which corresponds to the range of depth in feet (e.g., if depth = 0.46, range in feet = 0, or if depth = 1.72, range in feet = 1) is aligned with the stream depth value transposed to the vernier scale. This automatically positions the meter for use in the 0.6 method as the meter is then six-tenths of the total depth from the surface of the water.

For using the two-point method of velocity measurement, the depth of water is divided by 2. This value is set so that the meter will be at the 0.8-depth position from the water surface. The depth of water is then multiplied by 2, and this value is set. The meter will then be at the 0.2-depth position measured down from the water surface. These two positions represent the conventional 0.2- and 0.8-depth positions. If depths are less than 0.30 foot, the 0.5 method may be used. The observation depth recorded will then be 0.5 of the total depth.

5.2.5.2 Steps to be Followed in Measuring Discharge. If water quality or sediments are sampled in conjunction with discharge measurement, samples will be collected prior to making discharge measurements. The following steps are to be followed in discharge measurement:

- Evaluate the measurement location. Choose a location where flow is least turbulent. If the prescribed location is in a stream reach with highly turbulent flow conditions, try to select a location immediately upstream or downstream from the prescribed location. Flow should be visible from bank to bank. Eddies and slack

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water must not be present Neither the type AA meter nor the pygmy meter will be used for measuring velocities slower than 0.1 fps unless absolutely necessary

- Remove aquatic vegetation, ice, or other minor flow impediments. When such modifications are made, exercise great care to avoid unnecessary movement of sediments or the splashing of sediments or water onto field personnel. Allow flow to stabilize before the current meter measurement begins
- Position a tape about 1 foot above the surface of the water Secure the tape so that it remains taut and perpendicular to the channel
- Select a starting point at either the left bank (left edge of water, LEW) or the right bank (right edge of water, REW) LEW and REW are determined when facing downstream Record LEW and REW in the manner shown in Figure SW 4-3 on the Discharge Measurement Notes (Figure SW.4-4)
- Note the distance in feet, and the stream direction, that this cross section lies from the prescribed location For example, the note may read "25 feet downstream" or "15 feet upstream "
- Measure the width of the stream, in feet After selecting the Price AA or pygmy meter (see Table SW 4-2), follow guidelines in Subsection 5.1.2.1 to select the number of subsections in which to measure velocity attempting to measure no more than 5% of total flow in any one section, if possible
- After determining the distance desired between measuring points, commonly referred to as sections, measurement can begin. Record the time and bank at

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Party GCA MAS Comp. By MAS Checked By GCA
Width: Area: 0.698 ft² Gage Height:
Method: Type of Meter pygmy Spin. Before 40+ After 40+
Comments/observations:

Cross Section

Flow

Other

	DIST FROM INT POINT	WIDTH (FT)	DEPTH (FT)	OBSER DEPTH	REVS	TIME (SEC)	VELOCITY (F/S)		AREA (FT ²)	DIS- CHARGE (CFS)
							AT POINT	MEAN IN VERTICAL		
LEW	50	0.1	φ		—	—			φ	
	48	0.3	0.2		15	43	0.369		0.06	0.022
	4.4	0.4	0.38		3	70	0.07		0.152	0.011
	4.0	0.4	0.32		φ	—	—		0.128	—
	36	0.4	0.36		10	44	0.25		0.144	0.036
	32	0.4	0.36		7	52	0.16		0.144	0.023
	2.8	0.35	0.20		φ	—	—		0.07	—
REW	25	0.15	φ		—	—	—		φ	—
									0.698	0.092 cfs

Site ID SWφφ5 Date 5/1/90 Signature M. Shit
Total Discharge

Job No. 4011

Prepared by MAS

Date 03/01/92

COMPUTATION NOTES OF A
CURRENT-METER MEASUREMENT

FIGURE SW.4-3

DISCHARGE MEASUREMENT

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Flow at	0	10	20	30	40	50	60	70	75
Discharge									
Area									
Velocity									
At point									
Mean									
Area									
Depth									
Width									
Discharge point									

DISCHARGE MEASUREMENT NOTES

Date _____ Party _____
 Width _____ Area _____ V.L. _____ G.H. _____ Disch. _____
 Method _____ No. sec. _____ G.H. change _____ in. Sup. _____
 Method and _____ Her angle and _____ Sup. and _____ Meter No. _____
 Type of meter _____
 Date rated _____ for rod, other _____
 Meter _____ ft. above bottom of weight _____
 Spun before mass _____ after _____
 Mass plots _____ % diff from rating _____
 Weighing cable, sec. lost, upstr., downstr., side _____
 bridge _____ feet, min, above, below _____
 gage and _____
 Check-bar found _____
 changed to _____ at _____
 Correct _____
 Levels obtained _____
 Measurement rated excellent (2%), good (5%), fair (8%), poor (over 8%), based on following conditions: Cross section _____
 Flow _____ Weather _____
 Other _____ Ac _____
 Gage _____ Water _____
 Record removed _____ Intake flushed _____
 Observe _____
 Control _____
 Remarks _____
 G. H. of acre flow _____ ft.

SOURCE
GEOLOGICAL SURVEY
WATER-SUPPLY
PAPER 2175, 1982
(4011-940-0143-940)

Job No 4011
Prepared by MAS
Date 03/01/92

DISCHARGE MEASUREMENT NOTES

FIGURE SW.4-4

DISCHARGE MEASUREMENT

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which measurement starts on the discharge measurement notes as "REW Start 0000", using REW or LEW depending upon whether starting at the right or the left edge of the water

- Note the distance to the beginning edge of water from the initial point. The initial point is an arbitrary point on the tape, preferably zero, which lies on the shoreside of the stream. All station locations are recorded as distances from the initial point
- Proceed to the first station beyond the edge of water. Record the distance from the initial point on the discharge measurement notes. Place the wading rod into the stream so the base plate rests on the stream bed
- Stand downstream of the tagline or tape and face upstream. Do not stand behind or close to the meter. Raise the current meter on the wading rod so that it is well above the surface of the water
- Measure stream depth at the measurement point as indicated on the wading rod. Record the stream depth to the nearest 0.02 foot (for example 0.32 feet or 1.54 feet)
- Lower the meter to the required depth and record the observation depth. The observation depth as a fraction of total depth is 0.6, 0.2, 0.8 or occasionally 0.5.
- The technician will stand in a position that least affects the velocity of the water passing the current meter. That position is usually obtained by facing upstream with the arm fully extended. The technician will stand at about a 45-degree angle downstream from the wading rod. The wading rod is held in a vertical position

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with the meter parallel to the direction of flow. Avoid standing in the water when possible.

- Start the digital counter. After 40 seconds, stop the counter. Note that the counter reports velocity.
- If using the headset rather than the digital counter, start the stopwatch on the first click and begin counting clicks. The first click counted after starting the stopwatch is counted as one.
- After at least 40 seconds have passed, stop the stopwatch on a click. Record the number of seconds and the number of revolutions (clicks) on the same line of the notes as the recorded depth.
- Determine velocity as a function of elapsed time and number of revolutions from the velocity chart. Record velocity in the appropriate column. If the flow meter is not lined up parallel to the flow, the cosine of the angle that the flow direction is from parallel is needed to correct velocity values. This is done by the following:
 - Hold up a copy of the discharge notes.
 - Line up the dot (shown in the cosine of the angle column of the notes) with the number on the tape that designates the measurement point of the cross-section.
 - Rotate the note by pivoting at the dot until the edge of the note is aligned with the flow. Find the number along the notes perimeter that lines up with the tape. This is the cosine of the angle. Record this value for the station.

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- Proceed to the next station. Record the distance from the initial point to the station. Repeat measurements of depth and velocity. Continue in this manner across the stream.
- After recording the distance measurement at the last station, record the time at which the ending edge of water is reached (e.g. LEW [or REW] FINISH 1330).
- Note velocity and depth at the edge of water as zero.
- Evaluate and record the following: Flow characteristics, weather conditions, air temperature, water temperature, observer(s), type of meter, and remarks.
- If less than 20 subsections have been used for the measurement, repeat the measurement steps. Begin from the opposite bank from where the previous measurement began.

5.2.6 Discharge Calculations

Using a calculator as needed, calculate discharge on the discharge notes as follows:

- Use the distances from initial point to compute width for each subsection. The first width is computed by subtracting the first distance (edge of water) from the second distance, and dividing this quantity by two. The second width will be the difference between the third distance and the first distance, divided by two. For each subsequent width, subtract the previous station distance from the following station distance, and divide this quantity by two. The final width is calculated as the difference between the final distance and the second-to-the-last distance,

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divided by two Sum the width column and check to be sure that the calculated width equals the distance between the REW and LEW

- Multiply the width by the depth for each station to determine the area of each subsection Sum the areas to determine total area
- If the angle between the flow and the meter orientation is not 90 degrees, correct the measured velocity readings by multiplying the velocity by the cosine of the angle
- Multiply the velocity by the area for each station to obtain the discharge for each subsection
- Sum the discharges for each subsection to determine total discharge and record the value
- If two sets of discharge measurements beginning at opposite banks were taken, repeat the discharge calculations for the second set of data. Average the total discharges for the two measurements Record the average value and report it for input into the database

5.3 CONTROL STRUCTURES

Control structures such as weirs and flumes can be used to determine discharge. These structures have regular dimensions that allow for a consistent relationship between water level and discharge Five Parshall flumes are in operational condition at RFP, and more are to be installed. This section describes use of Parshall flumes to measure discharge With the exception of small v-notch weirs in pipes in and near the sewage treatment plant, no weirs are known to be in operation at RFP,

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therefore, this section provides general guidelines for the use of weirs in measuring discharges. Should weirs be installed at RFP, addenda to this SOP will be prepared to describe the use of the specific type of weir in discharge measurement.

5.3.1 Introduction

5.3.1.1 Weirs. Weirs are classified under the general categories of (1) broad crested, or (2) sharp crested. Discharge over a broad-crested weir takes the form

$$Q = CLH^{3/2},$$

where Q is the discharge, L is the crest length, and H is the depth of water over the crest of the weir. Values for the coefficient C are given in hydraulic handbooks. While the exponent for H listed here is applicable to many weirs, hydraulic handbooks should be consulted to find the correct exponent for the weir being used.

Sharp crested weirs are constructed in a variety of shapes, but the most common are V-notch, rectangular, and Cipolletti.

5.3.1.2 Flumes. A calibrated constriction placed in a stream channel changes the level of the water in or near the constriction. Flumes are constructed so that a restriction in the channel causes the water to accelerate, producing a corresponding change (drop) in the water level.

When the physical dimensions of the flume constriction are known, discharge through the constriction may be determined from measurement of depth. Refer to Subsection 5.1.3.6.2 for a description of discharge measurement for Parshall flumes.

Typical flumes consist of three sections

- A converging section to accelerate the approaching flow.

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- A throat section, whose width is used to designate flume size.
- A diverging section, designed to ensure that the level downstream is lower than the level in the converging section

The stage of a stream is the height of the water surface above an established elevation. Stage is usually expressed in feet. The Parshall flume consists of a converging section with a level floor, a throat section with a downward sloping floor, and a diverging section with an upward sloping floor (see Figure SW 4-5). The principal feature of the Parshall flume (developed by R. Parshall in 1922) is an approach reach having converging sidewalls and a level floor, the downstream end of which is a critical depth cross section. The primary stage measurement is made in the approach reach at some standard distance upstream from the critical-depth cross section.

The flumes are designated by the width (w) of the throat. Flumes having throat widths from 3 inches (in) to 8 feet (ft) have a rounded entrance whose floor slope is 25 percent. Smaller and larger flumes do not have that feature.

5.3.2 Required Measurement Conditions

5.3.2.1 Weirs For weir formulas to give accurate values of discharge, the upstream face of the weir must be vertical and at right angles to the channel, and the crest of the weir must be horizontal. In addition, atmospheric pressure should be maintained under the nappe, and the approach channel should be straight and unobstructed. The head, h, should be measured far enough upstream from the weir to avoid the affect of curvature of the water surface near the weir.

5.3.2.2 Flumes Ideally, flow rate through a flume may be determined by measurements at a single point some distance downstream from the inlet and above the throat.

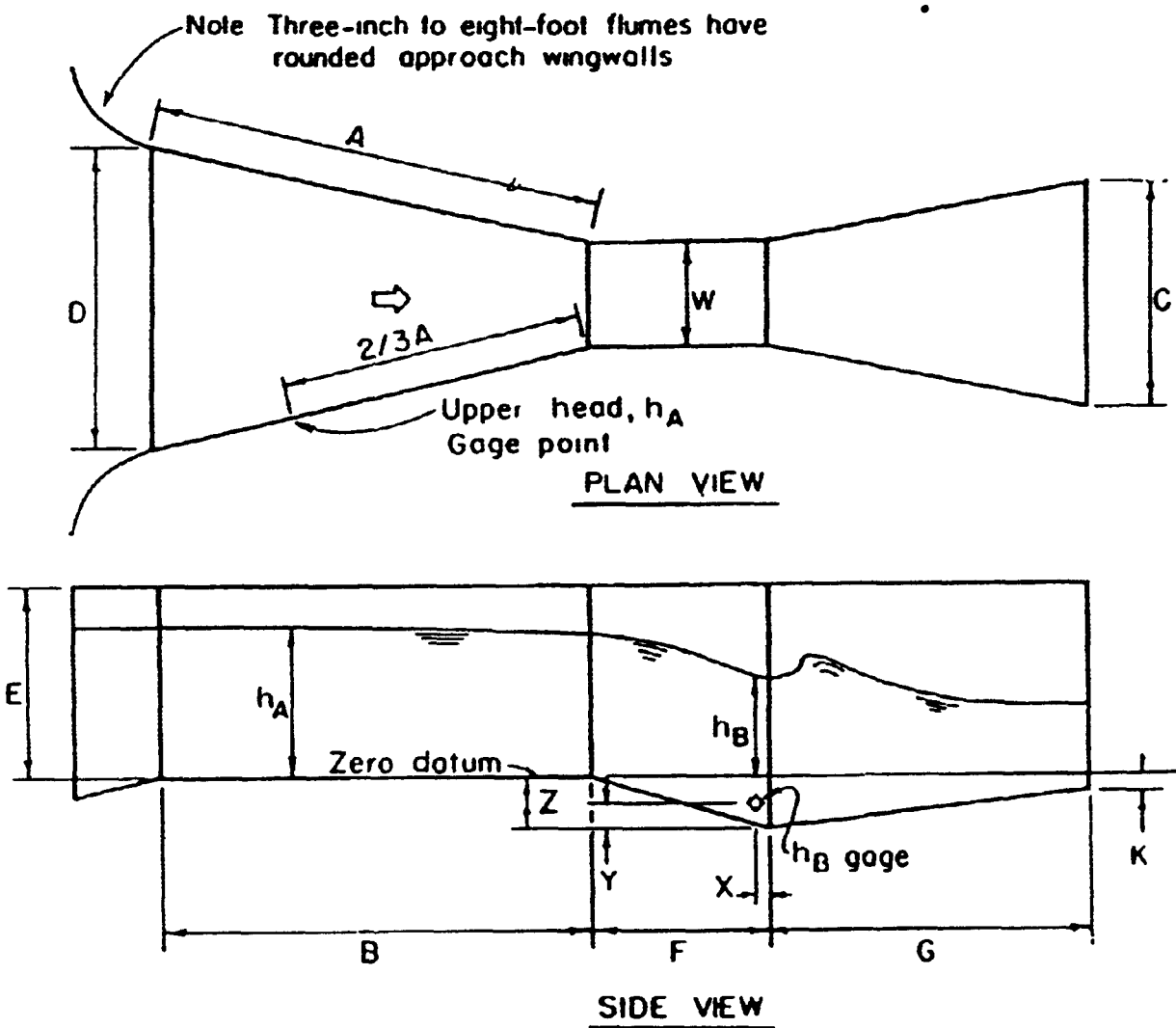
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FROM U.S.E.P.A. ENGINEERING SUPPORT BRANCH STANDARD OPERATING
PROCEDURES AND QUALITY ASSURANCE MANUAL

Job No. 4011

Prepared by MAS

Date 03/01/92

CONFIGURATION AND DESCRIPTIVE
NOMENCLATURE FOR PARSHALL FLUMES

FIGURE SW.4-5

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5.3.3 Equipment

The following equipment will be needed

- Current meter
- Carpenter's level
- Framing square
- Measuring tapes
- Staff gauge

5.3.4 Maintenance and Calibration Procedures

5.3.4.1 **Weirs.** All weirs will be inspected to determine that they provide a uniform influent flow distribution and that they are placed squarely across the channel. Corrosion of the crest of a sharp-edged weir or damage by floating debris may alter the weir coefficient. If a broad-crested weir is to be used for measurement purposes, its shape must conform to one for which coefficients have been established by testing. The equations and tables found in hydraulics references that are used to compute the flow over weirs apply only to free-flow conditions. When the water level downstream from a weir rises above the level of the weir crest, the weir crest is said to be submerged. Formulas have been developed for flow over submerged weirs, but under such conditions accurate flow measurement is not possible because surface disturbances downstream from the weir make it difficult to measure the depth of submergence.

5.3.4.2 **Flumes.** All flumes will be inspected to determine that entrance conditions provide a uniform influent flow distribution, the converging throat section is level, and that the throat section walls are vertical. The flume will be closely examined to determine that it is discharging freely. Any problems observed during the inspection will be noted and reported to the field manager.

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5.3.5 Procedures

5.3.5.1 Overview. In accordance with SW 1, Surface Water Data Collection Activities, the field crew will determine possible flow conditions based on past activities at the site before going to the field data site. Upon arrival at the site, the technicians will evaluate the flow conditions to verify the appropriate method for flow measurement. If the flow conditions meet those outlined in Subsection 5.1.3.2, then the technicians will observe and use judgment in approximating the flow volume and will perform a measurement based on use of the control structure.

5.3.5.2 Steps to be Followed in Measuring Discharge

- Remove any material that may have accumulated in the flume or on the weir
- If the station includes a chart recorder, inspect the strip chart on the recorder to verify that it is operating
- Note any deterioration of the station, report these conditions to the field manager at the conclusion of daily data collection activities
- Measure and record the throat width to the nearest 1/10 of an inch.
- Use the staff gage to measure and record the gage height to the nearest 0.02 foot
- Calculate discharge as described in Subsection 5.1.3.6
- Record the calculated discharge and the time and date of the site visit.

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5.3.6 Discharge Calculations

5.3.6.1 Weirs. Equations are derived for weirs of specific geometry which relate static head to discharge. Weirs are generally classified into two general categories (1) broad crested, and (2) sharp crested.

A set of weir tables is necessary for calculating flows. The weir tables are specific to the type of weir. If weirs are established at RFP, tables specific to the weirs will become an addendum to this SOP.

5.3.6.2 Flumes. A set of flume tables is necessary for calculating flows. The flume tables are specific to the type of flume. If flumes other than Parshall flumes are installed at RFP, tables specific to the flumes will become an addendum to this SOP. For Parshall Flumes refer to Table SW 4-3, Free-Flow Discharge-Parshall Flume, cfs. Based on the gage height (head, H, in feet) and the throat width of the flume (size of flume, W), the discharge is read directly from Table SW 4-3. Note that approximate values of discharge for heads other than those shown may be found by direct interpolation in the table.

6.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) activities will be accomplished according to applicable project plans as well as quality requirements in this SOP.

7.0 DOCUMENTATION

Information required by this SOP will be documented on the discharge measurement notes shown in Figure SW 4-4. These notes can be found in the Surface Water Data Collection Form (Form SW 1A). The form is found in SW 1, Surface Water Data Collection Activities. Data required by

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this SOP includes flow measurement device calibration information and field flow measurement data.

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Table SW.4-3

Free Flow Discharge -- Parshall Flume, cfs

Head, H, Feet	Size of Flume, H'										
	3"	6"	9"	12"	15"	18"	24"	30"	36"	48"	60"
0.1	0.028	0.05	0.09	—	—	—	—	—	—	—	—
0.2	0.082	0.16	0.26	0.35	0.51	0.66	0.97	1.26	—	—	—
0.3	0.154	0.31	0.49	0.64	0.94	1.24	1.82	2.39	2.96	3.52	4.62
0.4	0.241	0.48	0.76	0.99	1.47	1.93	2.86	3.77	4.68	5.57	7.34
0.5	0.339	0.69	1.06	1.39	2.06	2.73	4.05	5.36	6.66	7.94	10.51
0.6	0.450	0.92	1.40	1.84	2.73	3.62	5.39	7.15	8.89	10.63	14.08
0.7	0.571	1.17	1.78	2.33	3.46	4.60	6.86	9.11	11.36	13.59	18.04
0.8	0.702	1.45	2.18	2.85	4.26	5.66	8.46	11.25	14.04	16.81	22.36
0.9	0.843	1.74	2.61	3.41	5.10	6.80	10.17	13.55	16.92	20.29	27.02
1.0	0.992	2.06	3.07	4.00	6.00	8.00	12.00	16.00	20.00	24.00	32.00
1.1	—	2.40	3.55	4.62	6.95	9.27	13.93	18.60	23.26	27.94	37.30
1.2	—	2.75	4.06	5.28	7.94	10.61	15.96	21.33	26.71	32.10	42.89
1.3	—	—	4.59	5.96	8.99	12.01	18.10	24.21	30.33	36.47	48.78
1.4	—	—	5.14	6.68	10.10	13.48	20.32	27.21	34.11	41.05	54.95
1.5	—	—	—	7.41	11.20	15.00	22.64	30.34	38.06	45.82	61.40
1.6	—	—	—	8.18	12.40	16.58	25.05	33.59	42.17	50.79	68.10
1.7	—	—	—	8.97	13.60	18.21	27.55	36.96	46.43	55.95	75.08
1.8	—	—	—	9.79	14.80	19.90	30.13	40.45	50.83	61.29	82.29
1.9	—	—	—	10.62	16.10	21.63	32.79	44.05	55.39	66.81	89.76
2.0	—	—	—	11.49	17.40	23.43	35.53	47.77	60.08	72.50	97.48
2.1	—	—	—	12.37	18.80	25.27	38.35	51.59	64.92	78.37	105.40
2.2	—	—	—	13.28	20.20	27.15	41.25	55.52	69.90	84.41	113.60
2.3	—	—	—	14.21	21.60	29.09	44.22	59.56	75.01	90.61	122.00
2.4	—	—	—	15.16	23.00	31.09	47.27	63.69	80.25	96.97	130.70
2.5	—	—	—	16.13	24.60	33.11	50.39	67.93	85.62	103.50	139.50

NOTE Approximate values of flow for heads other than those shown may be found by direct interpolation in the table

From Groundwater and Wells, Second Edition, 1986